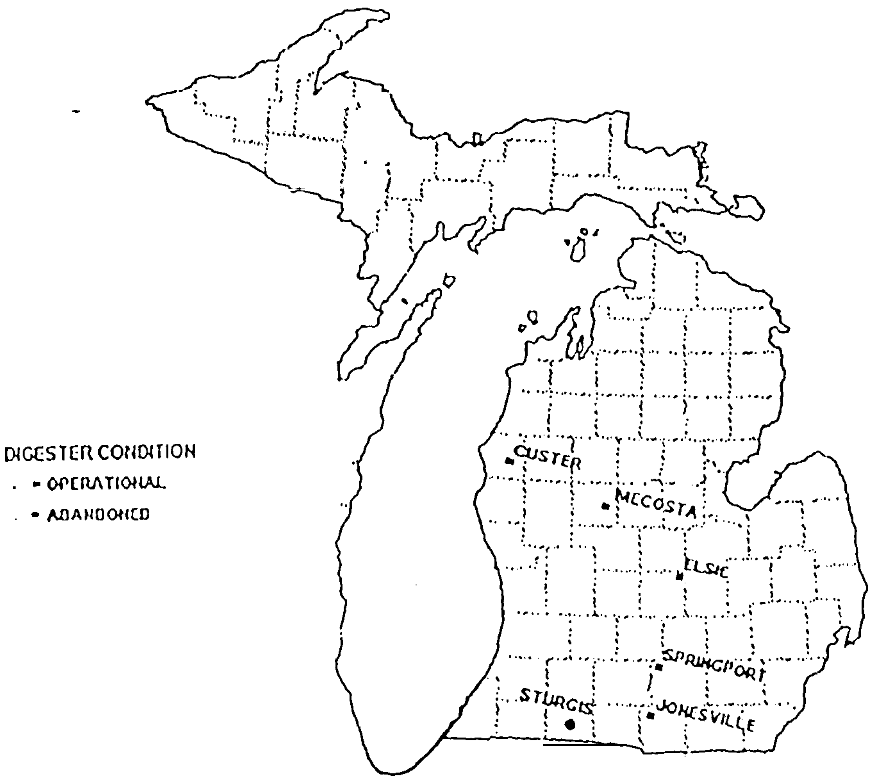
A REPORT OF THE
MICHIGAN BIOMASS ENERGY PROGRAM

FARM-BASED ANAEROBIC DIGESTION IN MICHIGAN

HISTORY, CURRENT STATUS, AND FUTURE OUTLOOK



Prepared By:

Jack L. Rozdilsky, MA
Coordinator, Michigan Biornass Energy Program

Lansing, Michigan
September 1997

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MICHIGAN BIOMASS ENERGY PROGRAM

The goal of the Michigan Biomass Energy program is to encourage increased production capacity for biomass energy derived from Michigan's resources by initiating program policies, disseminating information, and facilitating projects.

FARM-BASED ANAEROBIC DIGESTION IN MICHIGAN

HISTORY, CURRENT **STATUS,** AND FUTURE OUTLOOK

For fiscal year 1996-1997, the Michigan Biomass Energy Program (MBEP) **has** investigated the potential for a small farm-based demonstration project using appropriate biomass energy technology. This report is a direct product of that investigation[1].

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- *Disclaimer*

The views expressed are those of the author, and do not necessarily reflect the views of the Michigan Biomass Energy Program, the Energy Resources Division , the Michigan Department of Consumer and Industry Services or its staff.

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[1] The information published in this report is based on the work of the Michigan Biomass Energy Program from October 1996 to September 1997. The principal investigator for this report was the MBEP coordinator, Jack Rozdilsky. Jan Patrick, the MBEP's Program Manager, has provided guidance for this project.

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ABSTRACT --

FARM-BASED ANAEROBIC DIGESTION IN MICHIGAN: HISTORY, CURRENT STATUS, and FUTURE OUTLOOK

Jack L. Rozdilsky, MA – Coordinator, Michigan Biomass Energy Program
September 1997

In 1996-1997, the Michigan Biomass Energy Program has focused on investigating the potential for a small farm-based biomass energy demonstration project. Anaerobic digestion was the focus for this work. It was determined that there was a history of failed anaerobic digesters on Michigan's farms making it difficult to proceed with implementing a demonstration project. While working on this project, it became apparent that little information concerning anaerobic digestion has been made available to Michigan farmers and information gaps existed concerning the shared experiences farmers have had with anaerobic digestion. Therefore, this report will provide two things - information on the concepts of anaerobic digestion and case studies of anaerobic digester experiences on Michigan's farms. The report can then be used as a point of departure for considering why digesters have generally not been successful in Michigan. Ideas developed from such considerations can lend themselves to actions that can reverse this trend of failed digesters.

In this report, a successful anaerobic digester is defined as one that is in operation. In Michigan, over the past 25 years, there have been six attempts at farm-based anaerobic digestion. Only one digester has been successful at Fairgrove Farms in Sturgis. The Sturgis digester has been in operation since 1981, and it provides energy and manure management benefits to the farm. The anaerobic digesters located at farms in the following Michigan towns have been abandoned - Custer, Elsie, Jonesville, Mecosta, and Springport. The failure rate for Michigan farm-based anaerobic digesters is 83%. While these data are not encouraging to the farmer considering anaerobic digestion, it is a mistake to assume that these performance data alone are indicative of the appropriateness of this technology to Michigan farms.

There are a number of interrelated perception, technological, and economic factors that have contributed to the situation of only one of six Michigan digesters being successful. I suggest that poor initial digester design often led to technological problems that extended the payback period beyond the length of time which a farmer would consider economically feasible. A few large digesters failed in this way, establishing a negative perception of anaerobic digestion in Michigan's farm community. The history of failed projects along with the negative perception prevented any further attempts at digestion. Therefore, the future of farm-based anaerobic digestion in Michigan is uncertain. Any future digesters on Michigan's farms will need to be planned in a way where the digester's operation closely matches the farms resource management regime. The digester's value will need in to considered in both monetary and non-monetary terms including manure management, energy, and environmental benefits.

Section One: Introduction

Since 1972, anaerobic digestion has been used on farms in the United States. Yet, in Michigan, only one farm-based anaerobic digester is known to be in operation. The question of whether or not anaerobic digestion is an appropriate biomass energy technology for Michigan is central to this report.

During the last year, the Michigan Biomass Energy Program (MBEP) focused its efforts on anaerobic digestion. A project was designed to investigate the potential for a small farm-based demonstration project. In the conceptualization and planning phases of the project, it was determined that in addition to the one operational farm-based anaerobic digester in Michigan, five others had been abandoned. After establishing the history of all of the Michigan digesters, the project then shifted to determining why most digesters had not been sustainable. This determination was accomplished by interviews, literature research, and site visits. It became clear that technological, economic, and perception barriers had all contributed to the history of failed digesters in Michigan. A negative perception of this technology had developed within the farm community. This situation made it difficult to build a constituency in Michigan's agricultural community to support new initiatives with anaerobic digestion. Therefore, during the one year period the MBEP had programmatically allotted for this project, it was not possible to move toward the implementation phases of a farm-based demonstration of a new anaerobic digester. In fact, facilitating a situation which is conducive to establishing a new anaerobic digester in Michigan is not likely to be accomplished in the immediate-term.

The end result of this project has established two directions which the MBEP can choose to take. The first direction is to use this project as a basis for continuing to work toward implementing a farm-based anaerobic digestion demonstration. The second direction is to wait for a change in the circumstances that currently prevent farm-based anaerobic digestion from being accepted or encouraged in the farm community. With either course, this information should assist interested farmers in the establishment of an anaerobic digester. By being aware of past situations, there is a smaller chance that the same mistakes hindering the past development of anaerobic digesters will be repeated.

This report, "Farm-Based Anaerobic Digestion in Michigan," has two primary objectives. The first objective is to provide information explaining the basic concepts of farm-based anaerobic digestion. Since anaerobic digestion is not widely used in Michigan it is unlikely that many people are aware of this biomass energy technology. Second, a gap in information exists concerning the common experiences shared by Michigan farmers who have invested in anaerobic digestion. Therefore, the second objective of this report is to use a case study-type format (in section three) to compile information concerning all of Michigan's past and present digester projects into one text. This report can then be used as a point of departure for considering why digesters have generally not been successful in Michigan, and then determining what actions can then be taken in order to reverse this trend. It has been the case that Michigan's one successful digester project has been investigated and highlighted in national biomass energy publications, but the other digester projects have had little attention. In order to seriously consider anaerobic digestion in Michigan, one should look at both the successes and failures in order to determine what can be realistically accomplished.

Section Two: Anaerobic Digestion

2.1- Anaerobic Digestion and Biomass Energy

Biomass is considered as organic matter derived from plants or animals. Biomass energy is the use of the stored solar energy inherent in the organic molecules which make up living things. Biomass can be converted to energy and useful products through biochemical and thermochemical processes. These processes are combustion, dry chemical processes, and aqueous processes. In other words, biomass can be burned, converted to a gas, or changed to a liquid fuel. This report will focus on a specific type of aqueous process known as anaerobic digestion. The biomass material used as a feedstock for anaerobic digestion discussed in this report is animal manure. In anaerobic digestion, the manure is biochemically converted to a gas and then this gas is used as a fuel for generating energy.

2.2- Anaerobic Digestion Defined

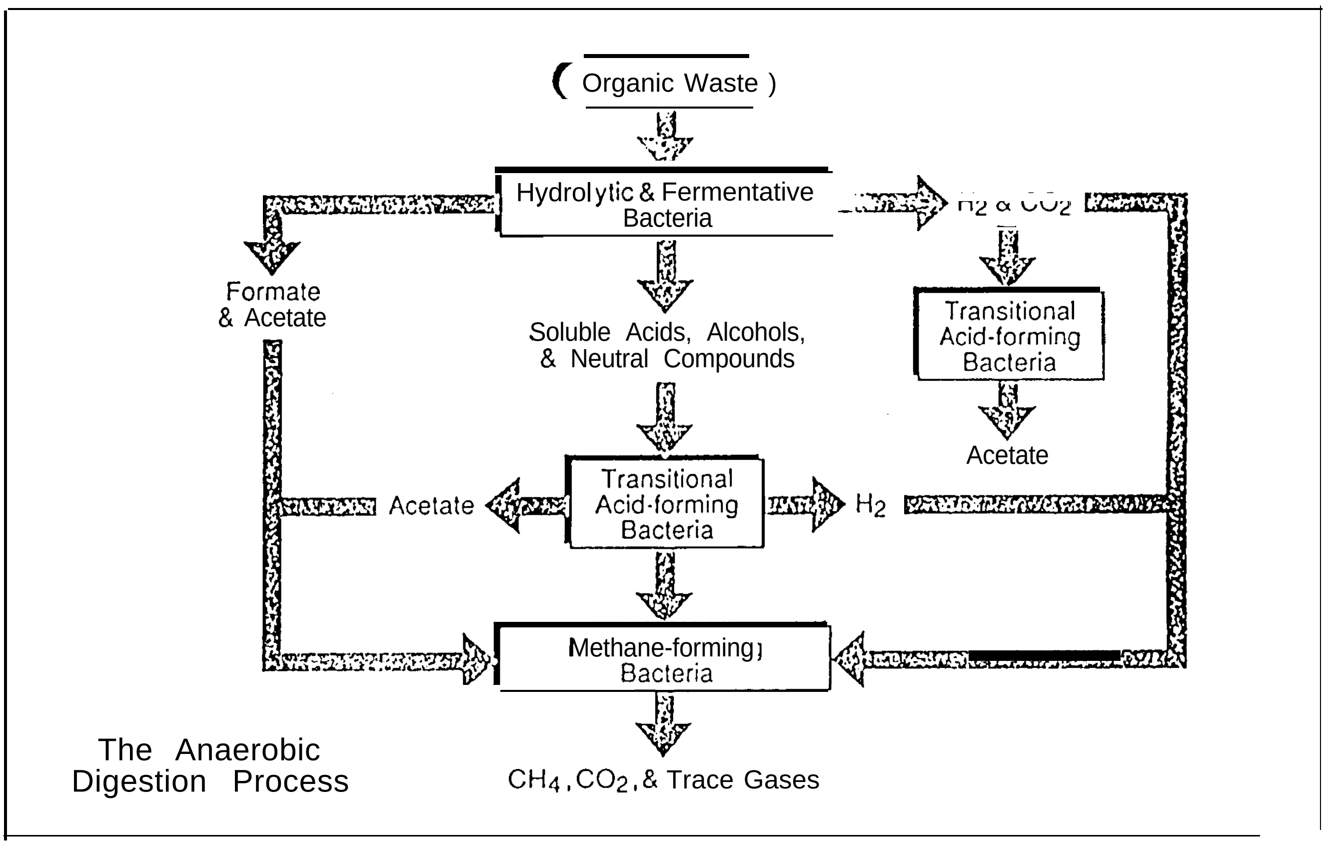
Anaerobic digestion is defined as the controlled decomposition of organic waste in an oxygen free environment. An anaerobic digester generally refers to a system consisting of a reactor tank where the degradation of organic matter by anaerobic microorganisms takes place. Besides the reactor tank, other components of the system include the parts for treating and processing the organic matter and the apparatus necessary for biogas collection, pretreatment, and use. For the remainder of this report, the entire system will be referred to as the digester.

2.3- The Anaerobic Digestion Process

A digester operates in a manner similar to an animal's digestive tract. The process of digestion is facilitated by the synergistic actions of four types of microorganisms: hydrolytic, fermentatative, acidogenic, and methanogenic. These specific types of microrgansims exist naturally in the manure and feed upon organic matter, successively breaking it down into its basic components. Generally, three biochemical processes take place in anaerobic digestion. First, liquefaction breaks down the constituent proteins, carbohydrates, and fats into simpler soluble molecules. As the products of liquefaction are too complex for digestion by methane forming bacteria, transitional acid forming bacteria further digest the organic matter producing acetate, hydrogen, carbon dioxide, and various nutrients. Then, methane forming bacteria can perform the task of anaerobic digestion by converting the acetate or hydrogen and carbon dioxide to biogas. The end product of anaerobic digestion, biogas, is a mixture of gasses consisting of methane, carbon dioxide, nitrogen, hydrogen, carbon monoxide , oxygen, and hydrogen sulfide. Methane makes up 55% to 70% of the biogas. Carbon dioxide accounts for most of the remainder of the biogas. Nitrogen, hydrogen, carbon monoxide, oxygen, and hydrogen sulfide occur in trace amounts. Figure #1 illustrates the anaerobic digestion process.

Figure #1

The Anaerobic Digestion Process



Source:

Great Lakes Regional Biomass Energy Program (US DOE), J.K. Cliburn and Associates (1993) Biogas Energy Systems - A Great Lakes Casebook. (Chicago: Council of Great Lakes Govenors)

2.4- Biogas: One of the Products of Anaerobic Digestion

The biogas produced by anaerobic digestion is similar in composition to natural gas extracted from wells. Therefore after scrubbing, the biogas produced by anaerobic digestion can be used to fuel internal combustion engines to run a generator that produces electricity. Typically biogas is used as a fuel to power engines, or it can be made available for sale. In 1988, it was determined that biogas supplied a total of about 0.12 quads of energy per year to the United States. Compared with the total national energy demand of about 80 quads, the use of biogas accounted for less than one-tenth of one percent of the nation's energy supply. In the late-1990's, this contribution of biogas has not dramatically increased.

2.5- Non-Farm Anaerobic Digestion

Anaerobic digestion can be applied to any site with a waste stream consisting of organic matter. Any facilities which process organic chemicals, milk, food, fiber, pharmaceuticals, municipal solid waste, or wastewater may have the potential to produce biogas from organic waste matter. For example, in the Great Lakes Region biogas is produced from landfill gas recovery, sludge digestion from municipal wastewater treatment plants, effluents digestion from breweries, and from the digestion of food processing waste. Future potential for biogas production may also exist by growing specific crops to be digested anaerobically.

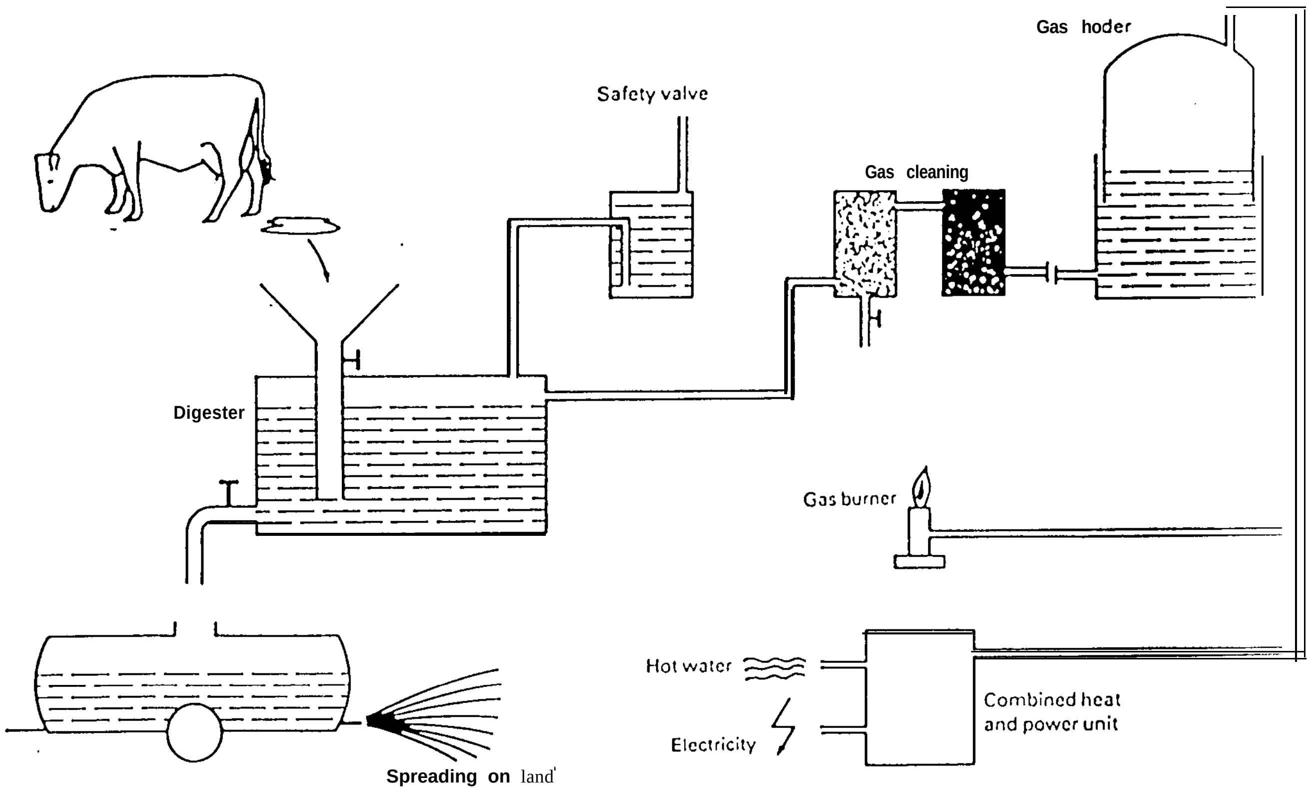
2.6 Farm-Based Anaerobic Digestion

On a typical farm, the digester will consist of the following parts: the livestock facility where the manure is produced, a manure handling system to get the manure to and from the digester's reaction vessel, the digestion reactor vessel, safety and gas cleaning equipment, the gas utilization system, and the apparatus for storing and using the digested manure byproducts. Figure #2 illustrates the basic elements of an anaerobic digestion system.

Since the inception of domestic farm-based digesters in the early 1970's, three types of digesters have been used. The complete mix type digester was the earliest digester design, followed by the plug flow type digester, and then the anaerobic lagoon type digester. Certain types of digesters have proven to be more suitable to specific types of farms and manure management situations than others. Many of the farm-based digesters are based on the same principles of operation as the small to medium size household digesters that operate in lesser-developed countries. However, the larger amounts of waste generation and energy requirements of the American farm have led to the design and installation of digesters based on principles originally developed for digesters at municipal sewage treatment facilities.

Figure #2

Basic Elements of a Farm-Based Anaerobic Digester



Source:

A. Wellinger, "Swiss Farm Experience of Anaerobic Digestion," in Anaerobic Digestion of Farm Waste. Ed. B.F. Pain and R. Q. Hepherd. (Reading, UK: National Institute for Research in Daitying, Technical Bulletin #7) 1985.

2.7- Types of Farm-Based Anaerobic Digesters

A complete mix digester's primary component is a large upright circular container. Manure is first collected and pumped to a mixing pit where the total solids percentage of the manure slurry is diluted. This slurry is preheated and then fed into the digester's reaction vessel, the upright circular container, where it is simultaneous heated and mechanically mixed. The manure slurry forms a homogenous substrate which spends 10 to 20 days digesting. The heating and mixing improve biogas production efficiency. A fixed cover is placed over the circular container to collect the biogas.

The plug flow digester consists of a long linear trough constructed at surface level or sometimes partially below grade. An airtight expandable cover is secured to the top of the trough. The manure is channeled from the animal stalls to a mixing pit where the total percent of the manure's solid content is reduced by adding water. From this mixing pit, a day's supply of manure (called a plug) is added to one end of the digester. Each day a new manure plug is added pushing the other manure across the trough. Over a period of 20 to 30 days, the manure passes across the digester, decomposes, and produces biogas. The gas is collected in the expandable cover.

On some farms, the manure management system starts with hydraulic flushing machines to clear manure from the animal stalls. On these farms, the complete mix and plug flow digesters would not be compatible with this flushing. However, an anaerobic lagoon type digester is suitable for these situations. In these systems, the manure is flushed to a lagoon where it digests for up to 60 days. A floating impermeable plastic cover is held in place on top of the lagoon with ropes anchored to concrete footings. The biogas produced under the top of the covered lagoon is trapped. A suction blower manifold device is then placed under the cover to remove the biogas, and it is piped to an end-use.

2.8- Recent Advances in Farm-Based Anaerobic Digestion

Some work has been done to simplify digester design in order to minimize construction and operating costs. One such design is the loop digester. This type of digester has a circular-shaped reactor with a fabric cover to collect the biogas. The loop design of the digester allows for convective currents to form in the digester to help prevent the crusting problems faced by linear plug flow digesters.

In addition, there have been recent technological developments in digestion although few been in use long enough to have an impact on the domestic marketplace. Currently available on a limited basis is a variation of the anaerobic lagoon digester called the advanced integrated pond system. This system uses a submerged canopy to cover a facultative pond where the organic waste is converted to biogas and stable residues. Effluent is then discharged into secondary pools to be used as a growth culture for algae. Other digestion technologies in the experimental stage, but not yet commercially available, include packed reactor digesters, upflow sludge blanket digesters, and sequenced batch reactor digester. These three types of digesters are being designed to reduce the number of days required for the anaerobic digestion process, however they still have higher levels of operational complexity and higher installed costs than existing systems.

2.9- Benefits of Farm-Based Anerobic Digestion

There are a number of reasons why using an anaerobic digester could be attractive to farmers. Digesters provide for important environmental benefits such a control of nutrient run-off, they reduce the amount of methane (a global warming gas) emitted, and they reduce the odor of manure matter. In recent times, situations of'urban sprawl have put farms right on the edge of urbanized districts. Complaints from neighbors about the odors from livestock manure have sometimes lead to the closing of the farm. A digester can reduce the odors from the farm, making it possible to for animal agriculture and residential development to peacefully coexist. In addition to the manure management benefits, one cannot overlook the energy produced. Even though it has sometimes been the case where the returns provided from energy are limited, any farmer would likely choose to have some return as compared to sunk costs associated with conventional methods of manure disposal. The energy provided from manure can help to shield the farmer from utility rate increases, reduce the costs of operating other machinery for manure managment and provide an alternative to disposal.

2.10- The History of Farm-Based Anaerobic Digestion in the United States

The primary source for much of the information in the next two sections has been compiled from reports by Philip Lusk, including Methane Recover-v from Animal Manures: A Current Opportunities Casebook, published in 1995 by the United States Department of Energy's Regional Biomass Energy Program.

In May of 1972, the nation's first farm-based anaerobic digester became operational on a farm outside of Mount Pleasant, Iowa. Due to urban sprawl encroaching on swine facility, a need existed to develop an odor-free method of handling farm waste. Due to an increasing number of complaints from surrounding residents, it became apparent that without a method to deal with the odors of the swine manure, the future of the farm would be in doubt. After reading a theoretical article on the digestion of swine manure along with technical assistance from the county extension service, the farmer constructed a crude complete-mix type digester from spare parts. As it was speculated, the digester produced a gas that could be easily be disposed of and a low-odor stabilized sludge.

Using the Iowa mechanisms as a basis, the first generation of complete mix digesters was built at Washington State University facilities. These developmental digesters faced numerous technical problems and had high start-up costs making them for the most part not-feasible for commercial operations. However, much of this work laid the foundation for the modern complete mix digester.

As the initial work on developing digesters continued into the mid-to-late 1970's, the energy crises resulted in a renewed interest in alternative energy. Investigations began to determine whether the small and medium size household digesters employed in India and China could be used on the American farm. In Asia, about six to eight million digesters were in operation. While these small digesters were not technically sophisticated, they produced enough energy for cooking and lighting at homesteads. This energy production was reflective of the fact that in the lesser developed nations of Asia and Africa, biomass fuel in the form of dung and wood can provide for a significant amount of the personal energy required for daily living. This situation contrasts the use of biomass energy in developed nation's when if its used at all, the energy supplied is supplemental and used for offsetting externalities of the existing energy supply system, diversifing the energy supply mix for specific facilities, or for providing for the economic advantages of energy self-sufficiency. It has often been easier to incorporate the ideas of appropriate technology into foreign development work as opposed to domestic projects. Without the advanced infrastructure for disposal of human waste, and the ability to deliver electricity from remote centralized generating stations, the need for a simple technology that can incorporate a_ high input of local waste resources and provide gaseous fuel for direct use is important.

At first, the systems of lesser-developed nations seemed to have little direct relevance to the American farmer's situation. However in the late 1970's, researchers at Cornell University reduced the operational complexities of the complete mix digesters by building on the principles of the Asian designs for small digesters and produced a new type of digester, the plug flow digester. In 1979 a dairy farm in Lancaster County, Pennsylvania was the first to use a plug-flow digester. Some of these digesters were enclosed in greenhouses or insulated. Plug-flow digesters were used to introduce the concepts of anaerobic digestion to the cooler climates of the Northeastern United States since they were found to maintain the temperatures essential to digestion better than the complete mix type digesters.

In the early 1980's, the idea of collecting biogas by placing a floating cover on an anaerobic lagoon emerged. This concept was important since at many farms the manure management system usually involves flushing manure to a lagoon. The first commercial application of using a floating cover to trap and collect biogas was applied at a sow-to-farrow finishing facility located in Tulare, California. The first full scale covered anaerobic lagoon digester was established in 1988 at a dairy farm located in North Carolina.

By the end of the 1980's, many of the digesters that initially started operation in the 1970's were in need of overhaul. Some of the farmers who employed digesters did an not apply an appropriate level of constant maintenance to the digester, partially due to a lack of experiential knowledge. Many digesters were abandoned in this time period. Also, as perception of need for conservation of energy was not strong, few farmers saw the need for exploring alternative sources of energy supply. During the early 1990's, there has been some renewed interest in farm-based anaerobic digestion primary due the manure management and odor reduction potentials. However, this interest has not been high enough for many new digestion. projects to be started.

2.1 1- Current Status of Digesters in the United States

Since 1970, approximately 81 digesters were considered to be built on dairy, swine, and poultry farms. Another 65 to 70 were installed or planned to be installed on research sites and a few beef farms. In the United States, a maximum of 150 digester projects have been undertaken. Comparatively, in Europe approximately there are approximately 470 existing biogas plants based on animal manure. Around 200 of those plants digesters are in operation in Germany.

Data has been gathered by Lusk and others on the 81 dairy swine and poultry **farm** digesters. Of these 81 digesters, 25 digesters are still in operation, 41 are not operating, and 10 were planned but never built. If a farmer chooses to embark on a digester project, the chance of a successful project is questionable since 65% of his/her colleagues who did the same have ended up with non-operating digesters. (See figure #3)

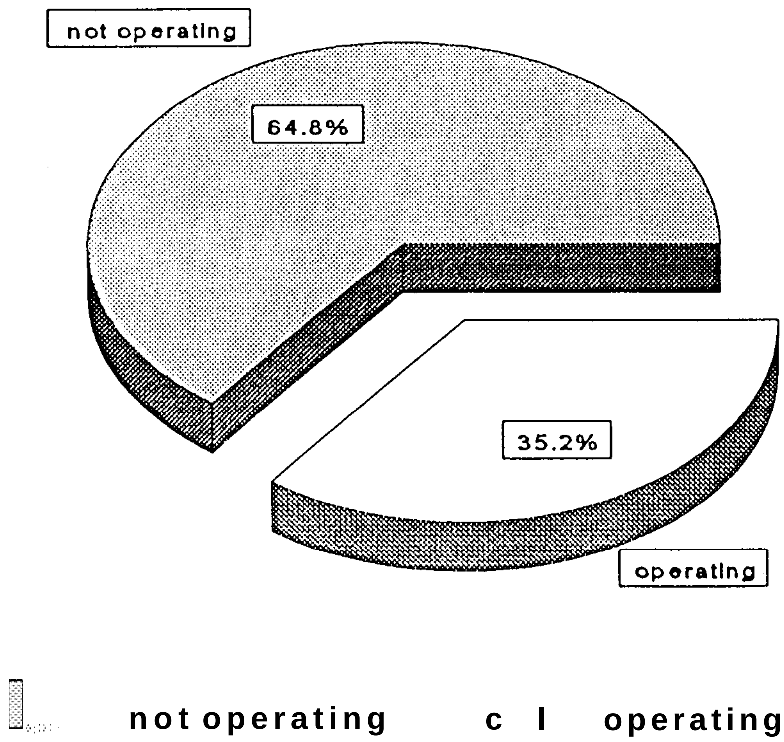
The leading cause for the high failure rate of digesters has been poor design and installation. Poor quality equipment and materials have been reported to be the second main cause for failed digesters. As with other alternative energy technologies, during the boom years of the late 1970's and early 1980's, many projects were rapidly thrown together. The perception of an impending energy crisis and the availability of government support for such projects facilitated many entrepreneurs to enter into the business of selling farmers digesters. Unfortunately, some entrepreneur's marketing schemes were ahead of their engineering skills. Farmers were often sold digesters based on inaccuarate estimates of the required maintenance time needed for the digester and overestimates of the short-term energy output. It was sometimes implied that digesters were basically a turn-key mechanism where after set-up all one needed to do was turn the key to start the machine, and then let it go. It was not fully explained that the machines being placed on commercial operations were just developed on experimental sites a few years earlier. During the 1970's and early 1980's, the use of digesters on farms was to some extent a new technology that brought with it uncertainties. Some farmers welcomed this challenge, and re-worked their digesters to get them to operate efficiently for site-specific needs. For others, the digesters became economically not feasible when the costs for maintenance and time diverted from other profit centers.

While there has been a questionable performance of farm-based digesters, **the** reasons for digester failure go beyond a poorly operating digester itself. Some **of the** failure rate is due to the facts that during the past three decades many small to medium size farms have gone out of business, or the operations have been consolidated and transferred to new owners. Without a training or background in the operation of digesters, a new farm owner inheriting a digester would be likely to let the digester become derelict as they are sometimes viewed as a non-essential apparatus in relation to the overall operation of the farm.

Figure #3

CURRENT STATUS OF ANAEROBIC DIGESTERS
UNITED STATES

Status of Farm-Based Digesters in the U.S. (1992)



Status of Farm-Based Digesters, by Type, in the U. S. (1992)					
	Slurry	Plug	Mix	Lagoon	Total
operating	5	9	4	7	25
not operating	0	30	13	3	46

Sources:

ICF Consulting Associates (1992) US Anaerobic Digester Farm Study. Unpublished report prepared for the US EPA.

Regional Biomass Energy Program (US DOE), Philip Lusk (Resource Development Associates) (1995) Methane Recovery from Animal Manure. (Washington D.C.: US Dept. Of Energy)

On a survey done by Lusk in the early 1990's, of the farmers who still use anaerobic digesters none regret there initial decision to use digesters on their farm. These farmers have had the common traits of using knowledge gained through practical experience to make digesters successful at their farms. These farmers are responsible for keeping the technology of anaerobic digestion alive in the United States.

Section Three: Farm-Based Anaerobic Digestion in Michigan

Since the late-I 970s, anaerobic digestion has been attempted on Michigan's farms. Of the six known farm-based digesters in Michigan, five have been abandoned and one continues to operate. While in the United States the chance for failure (owning a non-operating digester) is 65%, the Michigan chance for failure is 83% (see figure #4). While these data are not encouraging for a farmer considering anaerobic digestion, there have been many reasons for the abandoning of digesters. It is a mistake to assume that the performance data of the digesters in Michigan indicates that this technology is not appropriate for Michigan farms. Situations ranging from poor initial digester design to the closing of the farm have caused Michigan digesters to fail. This section will look at Michigan digesters on a case-by-case basis in order to illustrate the a range of the complexities that are involved in the operation of digesters.

The case studies of Michigan digesters were completed by site visits, personal interviews, and literature reviews. Site visits were made to Elsie and Sturgis. Telephone, personal, and e-mail interviews were used to gather information on the Custer, Mecosta, Springport, and Jonesville digesters. It should be noted that while all attempts were made to gather accurate information, some of the digester's original owners and operators were deceased, retired, or out of the farming business making it difficult to track down direct information. Also, some of the farmers were reluctant to talk about projects that they perceived as failures. It should be noted here that judgments on the relative successes or failures of any farmers are not intended, implied, or appropraite for this report. Rather, the farmers who have attempted anaerobic digestion in Michigan should be viewed as pioneers who have attempted to incorporate alternative energy into their farming system. In this view the failures are just as important as the successes when trying to figure out how to best consider using biomass energy on Michigan's farms.

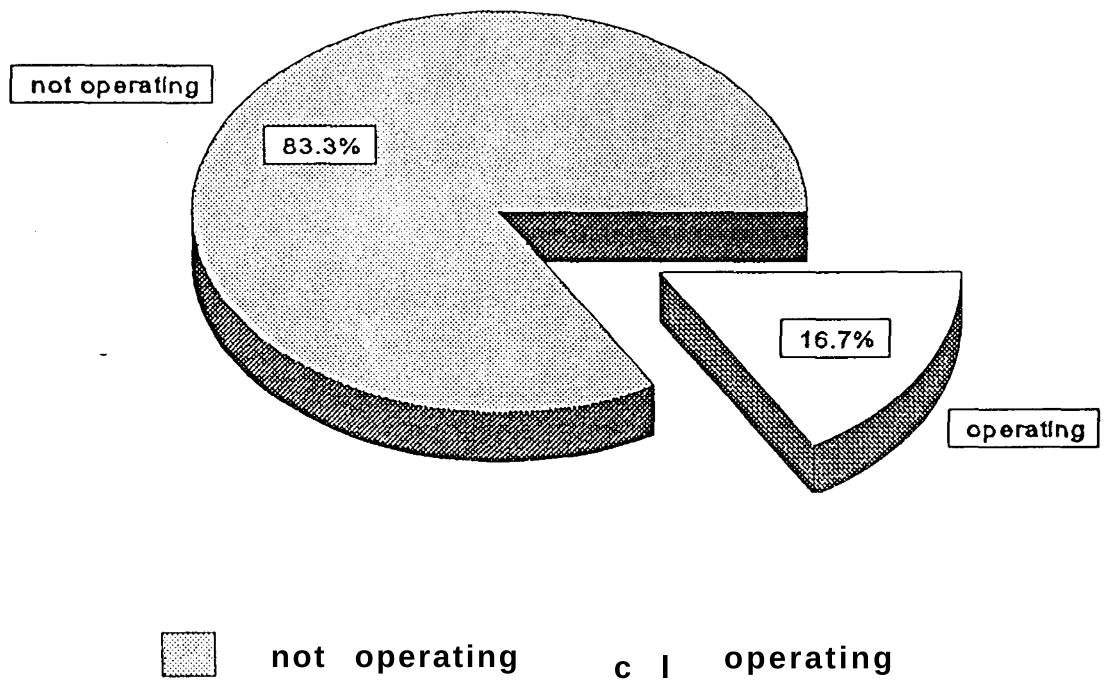
This section contains the following parts:

- Chart of the Current Status of Farm-Based Anaerobic Digesters
- Geographic Distribution of Farm-Based Anaerobic Digesters
- Case Study of the Custer Digester
- Case Study of the Elsie Digester
- Case Study of the Jonesville Digester
- Case Study of the Mecosta Digester
- Case Study of the Springport Digester
- Case Study of the Sturgis Digester

Figure #4

CURRENT STATUS OF ANAEROBIC DIGESTERS
in MICHIGAN

Status of Farm-Based Digesters in Michigan (1997)



Status of Farm-Based Digesters, by Type, in Michigan (1997)					
	Slurry	Plug	Mix	Lagoon	Total
operating	0	1	0	0	1
not operating	0	5	0	0	5

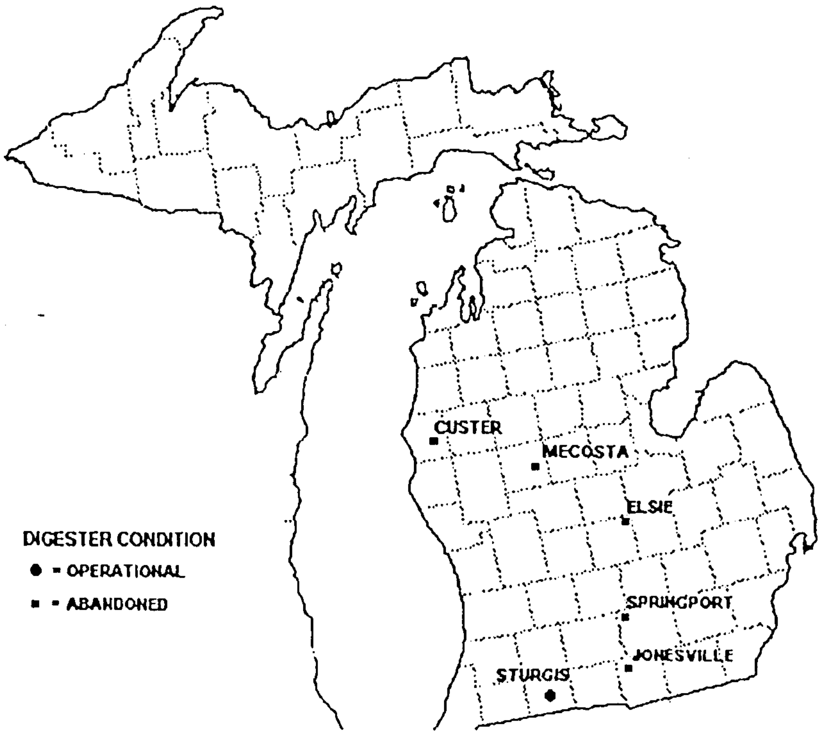
Sources.'

ICF Consulting Associates (1992)US Anaerobic Digester Farm Study. Unpublished report prepared for the US EPA.

Regional Biomass Energy Program (US DOE), Philip Lusk (Resource Development Associates (1995)Methane Recovery from Animal Manure. (Washington D.C.: US Dept. Of Energy)

Rozdilsky, Jack. (1997) Michigan Biomass Energy Program, Unpublished research report.

Figure #5
Geographic Distribution of Farm-Based Anaerobic Digesters in Michigan



All of the state's farm-based anaerobic digester are located in the southern two-thirds of the state's Lower Peninsula. If any future digester are constructed it is likely that they will be located in the state's farm belts in the southern Lower Peninsula.

The southern-central portion of the state's Lower Peninsula has excellent soils for agricultural production. Farming consists of mostly dairying and general livestock operations along with considerable corn production. As many of the existing digesters have been located in this region, new digesters could also be located at farms in this region.

The western coastal counties of Michigan have had only one digester. However, there are many dairy, poultry, and hog farms in this region. As environmental issues concerning animal wastes are associated with the larger animal production facilities in this region, anaerobic digestion may be able to be used to address manure management needs in this part of the state.

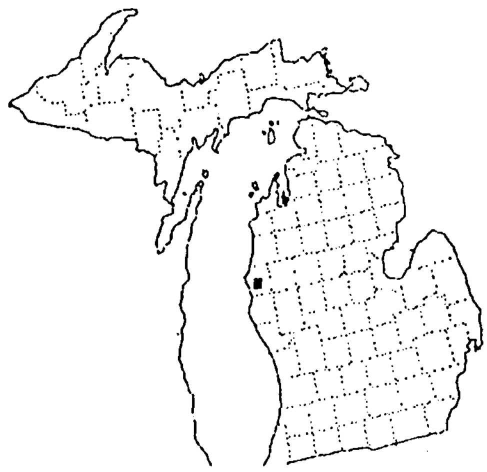
It is not likely that farm-based anaerobic digestion will spread into the urbanized southeastern portion of the state, or the state's Upper Peninsula. For most of the year, the winter climate of the Upper Peninsula would create many difficulties for the heat-based anaerobic digestion process.

Prepared by: Jack Rozdilsky September 1997

MICHIGAN BIOMASS ENERGY PROGRAM: MICHIGAN ANAEROBIC DIGESTER CASE STUDY

Custer Digester Summary

Current Condition: Abandoned in 1982 -Scrapped
Operation Status: Not Operational



Location: Custer, Michigan
Farm: James Allsion Farm
Farm Type: Beef Cattle Farm

Digester Starting Date: August 1979
Digester Ending Dale: August *1982*

Duration of Operation: 3 years

Equipment Status: digester razed and scrapped, farm sold

Digester Type: Plug-Flow
System Designer: Jerry Malestrom & Gene Dale
System Operator: farm owner

Initial Start-up Costs: $60,000 (in 1*979)*
Opera/ion Costs: not avoilnblc

Biomass Input
Digester Feedstock: Animal waste -- Beef Cattle Manure
Feedstock Quantity: Manure from a 300 head herd

Energy Output
Daily Average Electric Output: 600 Kwh
Energy Use: Electrical energy for powering heaters, feeding, and irrigation equipment

Reasons for Failure / Implications:

Two digesters were built, both of them were of an experimental nature. The first digcstcr was built for gathering test data, and the second digcstcr was used for producing biogas for on-farm applications. Malcstom and Dale were reported to have sold some scum suppression technology based on their work with the test digcstcr. The second digcstcr took two to three years to get to operate properly. Then, as the digester became operational, it required a level of maintenance that created a labor burden too great for a farm with a **staff** of three to absorb. The digcstcr was also designed in a wny which would have reached optimum performance on a farm with 500 to 600 head of cattle. This farm with 300 head of cattle was too small to allow for efficient operation of the digester. It was also found that about one-third of the energy produced by the digcstcr was nccdcd for its own operation (heating the reactor), ruiucing the overall efficiency of the system.

Despite the difficulties in moving from an experimental system to a practical on-farm system, Mr. Allison stated that the digcstcr performed very well in reducing the odor of the manure matter after it had passed through the digester. He suggested that the manure management benefits of the digester were a valuable result of the project. The Custer digester experience illustrates the importance of designing a digester appropriate to the size of the farm, and the need for initial digester design qualities that will that reduce the active maintenance needed for such systems.

Elsie Digester Summary

Current Condition: Derelict -Abandoned Since 1990
Operation Status: Not Operational

Location: Elsie, Michigan
Farm: Green Meadow Farms
Farm Type: Dairy Farm

Digester Starting Dale: 1983
Digester Ending Dale: 1990

Duration of Operation: 7 years

Equipment Status: non-usable, equipment remains on-site

Digesfer Type: Plug-Flow
System Designer: Energy Cycle Co. / Butler Manufacturing
System Operator: farm owner

Initial Start-up Costs: $792,000 (in 1983)
Operation Costs: $5,400 (yearly)

*Biomass **Input***
Digester Feedstock: Animal waste -- Dairy Cattle Manure
Feedstock Quantity: Manure from on 1,700 head herd

*Energy **Output***
Daily Average Electric Output: 2,500 Kwh
Energy Use: Electrical energy sent back to the utility's electric distribution grid

Reasons for Failure / Implications:

There were a number of interrelated economic, technical, and manngcmcnt reasons for the failure of this digester. The primary rensons were that the regulations in place required that electricity produced had to be sold back to the utility at a rate approximately four times less than the rate the utility would sell electricity to the customer, cost overruns occurred during the initial construction phases, the digester pit and the associated plumbing became clogged, the system did not mnintnin heat well in the winter, the bedding material was switched to sand which is generally not compatible with digesters, and the digester required more maintenance than expected. To solve these problems, a large amount of high-level management time had to be diverted from tending to the dairy cows to digester repairs. As the digester was not a profit center, such a practice of applying labor and resources to it could not be continued. All of these factors added up to the digester being not economically feasible After about seven years of operation, the digester had produced little net income and the amount of resources to keep it operating could not be justified. Many of the problems with this digester could probably be related to faults in the initial design. Also in the early 1980's, many technical problems were unforeseen as the technology was still partly cspcrimenta!.

The Elsie digester experience has important implications for the future of farm-based digestion projects in Michigan. Besides some of the technical lessons learned, the failure of this digester established a negative perception of this technology for Michigan's farm community. Elsie is known as Michigan's dairy capital and Green Meadow Farms is one of the state's leading dairy operations. The farm was both large enough and had enough resources to undertake such a project. After the difficulties experienced at the farm and the subsequent abandonment of the digester, the common perception emerged that if a digester can not be successful at Green Meadow Farms, a digester can not be successful at any dairy farm in Michigan. This negative perception will have to be removed in order for a new digester project to be successfully advanced on Michigan's farms.

Jonesville Digester Summary

Current Condition: Derelict – Abandoned Since 1988
Operation Status: Not Operational

Location: Jonesville, Michigan
Farm: Dale Baker Farm
Farm Type: Dairy Farm

Digester Starting Date: April 1985
Digester Ending Date: 1988

Duration of Operation: 3 years

Equipment Status: some of the **equipment remains** on-site

Digester Type: Plug-Flow
System Designer: Energy Cycle Company
System Operator: farm owner

Initial Start-up Costs: $100,000 *(* in *1985)*
Operation Costs: not available

Biomass Input
Digester Feedstock: Animal waste -- Dairy Cattle Manure
Feedstock Quantity: Manure from a 160 head herd

Energy Output
Daily Average Electric Output: 700 Kwh (design figure, not actual measurement)
Energy Use: Electrical energy for on-farm use

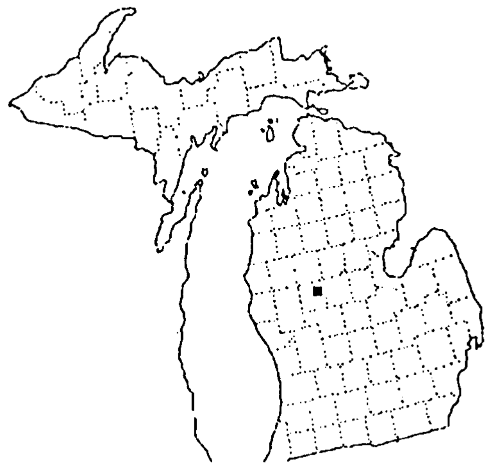
Reasons for Failure / Implications:

In *1985,* the period of time for the equipment to generate enough income to pay for the start-up costs was estimated to be 4.25 years. In 1988, it was surmised that after three years of operation the digester was not economically feasible and could not reach the payback point within the 4.2.5 year period. As the continued operation of the digester would become burdensome, the project was discontinued.

Factors such as the design and sizing of the digester may have played roles in the poor functioning of the system. The digester consisted of a steel tank laid on its side and a 20 foot by 20 foot hypalon (plastic) bag was used for gas storage. Using plastic gas bags for the collection and storage of digester produced biogas has not been a successful technology in Michigan. This failure may be due to the effects of the digester heat loss via the gas bag during the long winters. Using plastic gas bags for the collection and storage of biogas may not be appropriate for Michigan farms. This digester was not able to meet the expected payback period, so the initial investment could be not be recouped in a reasonable period of time. This experience suggests that it may be optimistic to expect a payback period of four years for a digester located in Michigan.

Mecosta Digester Summary

Current Condition: Abandoned in 1988 -Scrapped
Operation Status: Not Operational



Location: Mecosta, Michigan
Farm: Roy Thompson Farm
Farm Type: Dairy Farm

Digester Starting Dare: November 1984
Digester Ending Dale: 1988

Duration of Operation: 4 years

Equipment Status: digester razed and scrapped, farm sold

Digester Type: Plug-Flow
System Designer: farm owner
System Operator: farm owner

Initial Start-up Costs: $60,000 (in 1984)
Operation Costs: not available

Biomass Input
Digester Feedstock: Animal waste -- Dairy Cattle Manure
Feedstock Quantity: Manure from a 1 GO head herd

Energy Output
Daily Average Electric Output: 360 Kwh (design figure, not actual measurement)
Energy Use: Electrical energy to run heaters

Reasons/or Failure / Implications:

After a year of operation, the digester did not meet the biogas production output expected from the initial design specifications. As the digester operated below the expected level of performance, the system became economically not feasible. During its operation, the digesterbecame plugged with debris and then soap contaminated the digester. Sand from the cattle's freestalls gummed up the digester and caused it to function poorly. All the these factors added maintenance costs and worsened the digester's performance.

Factors such as the design and sizing of the digester may have played roles in poor functioning of the system. The period of time to break even on costs also would have exceeded a reasonable payback period of four years. These points imply that an initial robust design, prevention of sand from entering the digester, and not establishing a strict espectation for a payback period of four years arc important factors to be considered when attempting to plan and operation a digester.

Prepared by: Jack Rozdilsky **September 1997**

Springport Digester Summary

Current Condition: **Derelict -Abandoned** Since 1985
Operation **Status:** Not Operational

Location: Springport, Michigan
Farm: Floyd Baum Farm
Farm Type: Dairy Farm

Digester Starting Dare: June 198 *1*
Digester Ending Date: 1985

Duration of Operation: 4 years

Equipment Status: some of the **equipment** remains on-site

Digester Type: Plug-Flow
System Designer: Roland and Schaeffer / Energy Cycle Co.
System Operator: farm owner

Initial Start-up Costs: $220,000 (in 198 1)
Opernfiotr Costs: $15,000 (yearly)

*Biomass **Input***
Digester Feedstock: Animal waste -- Dairy Cattle Manure
Feedstock Quantity: Manure from an 800 head herd

Energy Output
Daily Average Electric Output: 1,4 13 Kwh
Energy Use: Electrical energy for an on-farm ethanol production facility

Reasons for Failure / Implications:

The primary reason for ceasing the operation of this digester had not so much to do with the digester itself as it did the closing of a related on-farm ethanol production facility. In the mid-1980's, the anaerobic digester was abandoned at the same time as the on-farm ethanol production facility was dismantled. When the ethanol plant became not economically feasible, the primary reason operating the digester disappeared.

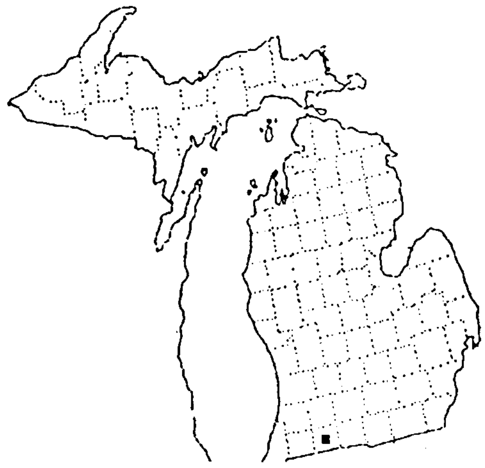
When the digester was in operation, Mr. Baum was generally satisfied with its operation. It was estimated that the digester created 32,500 cubic feet of biogas per day and generated 1,4 13 Kwh of electricity was daily. At the early 1980's electricity rate of $0.06 per Kwh, it can be estimated that the digester would **produce** $85 of electricity per day or the equivalent of about $30,000 of electricity per·year. In that case, the payback period for the initial start-up costs would be about seven years. It is questionnble whether that payback period is acceptable for a small to medium size farm.

Mr. Baum noted that when the digester was abandoned in 1985, h-c witnessed biogas bubbles being generated for another six years. During the operation of the digester, its primary benefits were reducing the amount of labor required for manure management, reducing the odor of manure matter, and the energy produced. Mr. Baum also stated the digester could have actually have been designed to be larger. This digester experience implies that perhaps a digester designed smaller than the maximum allowable size may be more manageable than the very large systems. One can speculate that a smaller digester can be more easily fme tuned to provide useful manure management and power production benefits for the specific needs of a small farm

Sturgis Digester Summary

Current Condition: **Operational Since** 1981
Opcration Status: Operational

Location: Sturgis, Michigan
Farm: Fairgrove Farms
Farm Type: Dairy Farm



Digester Starting Date: October 198 1
Digester Ending Date: **not** applicable

Duration of Operation: *16* years

Equipment Status: *working* but aged, requires upkeep

Digester Type: Plug-Flow
System Designer: Perennial Energy Inc. / farm owner
System Operator: farm owncr

Initial Start-up Costs: $ 150,000 (in 198 1)
Operalion Costs: $2,000 - $3,000 yearly

Biomass Input
Digester Feedstock: Animal wastc --Dairy Cattlc Manure
Feedstock Quantity: Manurc from a 750 head herd

Energy Output
Daily Average Electric Output: *85* Kwh
Energy Use: Elcctrical cnergy **for on-farm** usc

Reasons for Success / Implications:

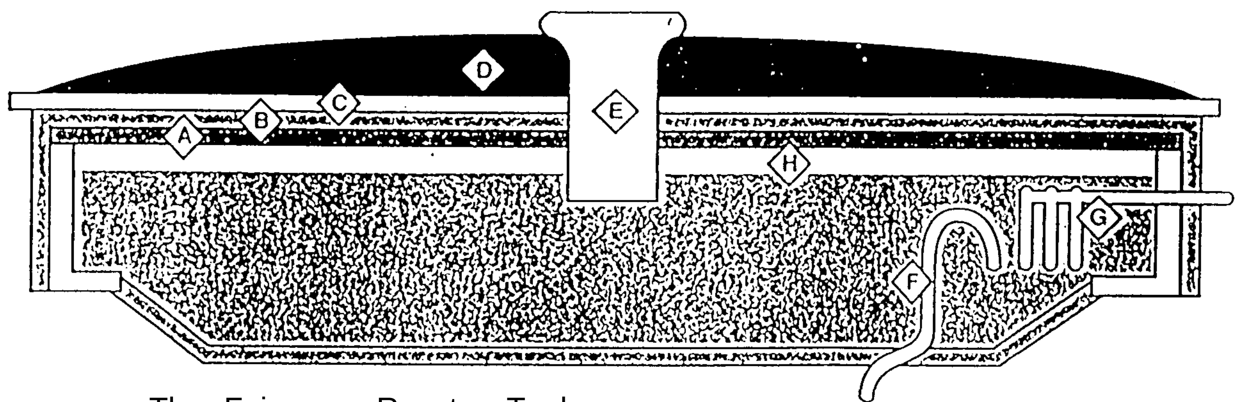
Thc **digcstcr at Fairgrovc Farms is** thc **only** opcrating **farm-based** anacrobic digcstcr **in** thc **state of Michigan.** Fcaturcs **of this** digcstcr **that** dircctly contributc **to its** succcssful **operation arc** cmbodicd **in its design qualities. The digcstcr's** rcactor **is** buricd two fcct below **the surface,** and covcrcd with an insulated stress corc top that has a four inch concrctc covcr (scc figure #6). **This** undcrground dcsign allows it lo bc morc compatiblc with Michigan's winter climatc. Also, aftcr thc initial installation somc troublc-causing, non-csscntial picccs of equipment wcrc rcmoved from thc apparatus. The digester's operators, the Pucschcl Brothers, can be said to bc "screwdriver friendly". Their mechanical skills along with their ability to modify and repair the system arc an important factor in the digcstcr's successful opcration. Portions **of the digcstcr hnvc bccn ovcr-enginccrcd, but** thosc **modifications** havc allowcd **for** thc digcstcr **to** stay in operation for thc last 16 ycars. The digester is reaching the end of its estimated 20 year lifc span, but with a fcw rcpairs it can likely last longer than thc expcctcd lifcspan. Instcad of technical **factors, it is more** likcly that human factors (such as farm manngcmcnt dccisions, ownership, etc.) will limit thc opcration of this digcstcr.

Thc primary benefits of this digcstcr arc its abilitics to rcducc thc odor of trcated manurc, to crcatc a uscful bcdding matcrial out the digcstcd manurc mattcr, and to providc energy. Monthly, thc digcstcr providcs enough clcctricity to avoid about $4,000 a month in clcctric bills and it also produces approximately $3,000 in bcdding material. The digcstcr produced cnough incomc to pay for its initial start-up cost in four years. Since operation and maintenance costs arc about $2,000 to $3,000 a year, after thc digcstcr gcncratcd cnough incomc to pay back its start-up costs, it has become a profit centcr for the farm.

The primary implication that the Sturgis digester has for farm-based digestion **in Michigan is that it illustrates how** anacrobic **digestion** can be succcssfully uscd on a Michigan farm. The digester's operation showcd that the integration of the digester into the farm's overall operation and managcmcnt plans is very important to its successful operation, having staff who have the ability to re-enginecr the system and solve problems without external help is csscntial, and an over-engineered relatively simple digester is the easiest to repair, most resilient, and most cost effective. Once the farm established the rules for the successful operation of the digcstcr, its management time has been minimal.

Figure #6

Diagram of the Sturgis (Michigan) Anaerobic Digester's Reactor Tank



The Fairgrove Reactor Tank

A Slrcss-core lop
B Four-inch foam insulation
C Four-inch concrete cover
D Two feet of topsoil
E Baffled inspection hole
F Effluent inlet from barn
G Heat exchanger
H Gas area (18 inches high)

Source:

Great Lakes Regional Biomass Energy Program (US DOE), J.K. Cliburn and Associates (1993) <u>Biogas Energy Systems - A Great Lakes Casebook</u> (Chicago: Council of Great Lakes Govenors)

Section Four: Barriers to Farm Based Anaerobic Digestion

4.1- Three Types of Barriers to Farm-Based Anaerobic Digestion

As has been the case in Michigan, 83% of the farm-based anaerobic digestion projects that were attempted have failed. While there are many interrelated reasons for the poor performance of this biomass energy technology, we could say that in Michigan, digesters can not be considered as a fully developed technology. Other than the Michigan Biomass Energy Program, the last time a state government agency looked at biomass energy on farms was in 1981 when a publication, Alternative Energy Handbook, was made available by the Michigan Department of Agriculture (MDoA). In 1983, the Agricultural Energy Section was at MDoA was discontinued. Little has been done by the state's universities or farm advocacy groups to develop anaerobic digestion on farms. If active programs had been available to follow-up on the failures, adaptations specific to Michigan farm could have been developed. Then, the lessons of the failures could have been built upon, and the technology would have been more advanced today. Since this has not been the case, we-have concluded that anaerobic digestion is not a fully developed technology in Michigan. At Michigan farms anaerobic digestion technology is in the limited-use stage. Given this situation, and after looking at the six attempts at digestion at Michigan farms, three types of barriers face anaerobic digestion on farms -- perception barriers, technological barrier, and economic barriers.

4.2- Perception Barriers

The first perception barrier preventing the use of anaerobic digesters on farms in Michigan is that farmers know the unknown by the known. A farmer is more likely to be familiar with a colleague who has an abandoned digester than a colleague who has a working digester. A very large digester at Green Meadow Farms in Elsie was abandoned after seven years of operation and this failed digester project had a high visibility in the farm community. When a failed project takes place at a respected dairy operation, a general attitude has been developed which is reflected by the statement, "If the digester can't work at Green Meadow Farms, a digester can't work at any farm in Michigan." Despite the working digester at Sturgis, this success is overshadowed by the more numerous failures. Until the farm community's negative perception of anaerobic digestion can be displaced, it will be difficult to convince many farmers that it is worth their time to consider using an anaerobic digester. When farmers are asked to consider the unknown (anaerobic digesters), their reaction to this new information is shaped by what is known by experience (failed anaerobic digesters).

A second perception barrier is a misunderstanding of the management needs for a digester to operate. The successful operation of a digester is a much more management intensive project than was expected by most Michigan farmers. For an anaerobic digester to be successful, it has to be treated as a living entity. This requires that high-level management time be used to maintain a healthy digester. On smaller farms, where the labor is stretched over a variety of tasks, the direction of high-level management activity away from the farm's profit center (cattle) to an energy production system is not seen as good management practice. Furthermore, most dairy farmers have no willingness to take on another active maintenance project. The main focus on a dairy farm is the cows, not an energy production apparatus. With the trend in management of farms moving toward specialization, the dairyman has a strict focus on cows and anything else is seen as diversion. A maxim among farmers is "to keep the main thing the main thing."

A third perception barrier to the successful operation of Michigan digesters was the change in external influences which caused a change in attitude toward such projects. When most of the Michigan digesters started their operation (mid-1970's to the early 1980's) the nation was midst of the second oil shock of the 1970's. The American public's perception was that the nation's energy supply was unstable and energy prices would continue to rise for the foreseeable future. The farmer's who started the digesters during this time saw these projects at a way to buffer themselves against the energy cost fluctuations caused by the energy crisis and at the same time become more energy independent, Simultaneously, the Federal Government offered incentives for farmers to experiment with alternative energy systems. In the late 1970's and early 1980's, farmers could both forward their own best interests and have a good chance of getting government support for such project. As the Reagan administration withdrew support for alternative energy programs, the financial support for digesters dwindled. Also, as the energy crisis became less intense during the mid-1980's, the operation of digesters became a less attractive proposition. However, a farmer who started an anaerobic digester during the time of high energy costs may have realized the benefits of the energy savings for that time period, but when energy costs lowered and government support dwindled, the farmer still had to pay the operation and maintenance costs for producing his / her own energy. A competitor's farm could then could buy energy for the same rate (or a lower rate) and not have to absorb the operation and maintenance costs of providing their own energy. Digesters had lost their competitive advantage, due to a change in circumstances external to farmers.

A fourth perception barrier, is that there is a lack of interest and support for such projects amongst Michigan farm advocates and farm service entities. For a statewide initiative to be successful, it would require that key farm stakeholders and farm opinion leaders support the idea of setting up anaerobic digesters at Michigan farms. When meeting with individual farmer's and with farm service entities, there was little support for advancing use of farm-based anaerobic digesters. I was constantly referred to the digestion projects that failed. If asked by a farmer if anaerobic digestion is worthwhile to consider, most farm service organizations in Michigan would not recommend anaerobic digestion as a feasible option. The lack of strong advocates for anaerobic digestion by farm community opinion leaders, combined with a record of more failures than successes does much to reduce the chances of starting another anaerobic digestion project in Michigan. The MBEP acting alone cannot be effective in encouraging a new look at this technology without the support of the farm community.

4.3- Technological Barriers

The primary technical problem facing digesters in Michigan is sand clogging the digester. This is a very complex problem to solve since it involves many factors, revolving around the choice of bedding material. In animal housing quarters, bedding material is necessary to provide comfort to the animals, to keep them clean, and to absorb liquid manure. For every gallon of milk, thirteen pounds of manure are created. The bedding material is put in place to help provide for an efficient method of collecting animal wastes while maintaining the nutrient value of the wastes for recycling. The bedding material and manure mix together to form a slurry which is cleared out of the housing areas by scraping or draining. This material is fed into the anaerobic digester. Sand laden manure is not compatible with the anaerobic digestion process since it clogs the digester's intake pipes, reduces the efficiency of the digester, and accumulates in the reactor preventing the formation of biogas.

Common organic bedding materials used are straw, sawdust, shavings, sand, spent mushroom compost, braken, peat, and newsprint. Bedding material has close and lengthy contact with cows teat ends. If there are pathogenic bacteria in bedding material incidence of infection can occur. One such infection is Masticis, the most costly disease effecting dairy cattle. The disease results in partial or total destruction of the milk synthesizing tissues and it becomes generalized resulting in the death of the animal. One pathway for environmental Masticis bacteria to enter the cow is through the housing system, specifically the bedding. Unlike organic bedding material, the smaller grain sizes of sand create a situation where bacteria have much less likelihood to survive. Sand also dries much faster than inorganic material. Sand is used for bedding for two primary reasons -- it is available locally and inexpensive, and it prevents cow diseases. In the late 1980's most Michigan farms switched to sand bedding. It has been estimated by Michigan State University that more than 50% of Michigan's dairy production is in freestall barns, and 50% of these farms use sand as bedding.

On most Michigan dairy farms, the farmer would not be amenable to switching from a sand bedding material to another material due to its easy availability and disease prevention qualities. A management regime designed for cow health would take precedence over a management regime which allows for the efficient operation of an anaerobic digester. Some experimental work has been done to develop mechanical sand separators to install between the free stalls and the digester, but these devices are still experimental and therefore costly to the farmer.

At the Elsie digester, when the switch was made to sand bedding the digester was for the most part rendered ineffective. However, it should be noted that at the Sturgis digester despite the use of organic bedding material there have been few problems with cow health.

Other than the technological problems caused by the selection of bedding material, poor initial design and poor installation have contributed to the failure of digesters, In the late 1970's and early 1980's, -technologies were put into the field that were unreliable prototypes produced by organizations with little understanding of the circumstances of the users. As with other forms of alternative energy, some entrepreneurs had marketing schemes which were more advanced that their engineering plans. This situation left a number of abandoned digesters, wind generators, and solar systems scattered around the Midwest tarnishing the image of alternative energy and effectively killing the market for alternative energy devices for many years.

Specific technological barriers related to design observed at Michigan digesters include the climate and the handling of the hydrogen sulfide trace gas. As anaerobic digestion is a heat-based process, some of the Michigan digester's reactor tanks have had trouble maintaining the ambient heat necessary for digestion to take place during the winter months. During Michigan's winter months, the amount of biogas production at some digesters decreased. It was also observed that one of the products of digestion, hydrogen sulfide gas, is very corrosive to the digester / biogas production housing and associated apparatus. While it is possible to use an iron sponge scrubber to purge some of this corrosive gas, the situation still creates a need for additional maintenance and the replacement of corroded parts.

On a final note, when Michigan's digesters were established, the technology was just moving out the experimental stage, and in many ways using digesters commercially was still experimental. Some of the Michigan farmer's who used digesters may have had a mistaken understanding that digestion was a proven technology. At the Sturgis digester, an attitude was taken where many adaptations were made in the spirit of experimentation. This factor was very important to the success of the digester at Sturgis. However, other fanners may had the impression that the digester is a turn-key apparatus where it can just be put to work with little experimentation. A general misunderstanding of all the complexities of anaerobic digestion technology was a likely a barrier to the successful operation of commercial digesters on farms.

4.4- Economic Barriers

Directly related to many of the issues previously discussed as perception barriers and technological barriers, economic barriers have prevented digesters from successfully operating. Key economic barriers have been from forces both internal and external to the farm.

Internal to the operation of the farm, a farmer is faced with high start-up costs when considering a digester. During the 1970's and 1980's, start-up costs for Michigan digesters ranged from $60,000 to $720,000. A digester can be considered as piece of equipment, yet one can not exactly calculate the economics in the same way that one would calculate the economic of other equipment, like tractors. A digester is similar to a living things in that it is not possible to exactly determine its output over a period of time. From discussions with Michigan farmers, the acceptable period of time that piece of equipment can be expectation to pay for itself (the payback period) is two to four years.

Payback period decisions are made on the basis of the time it will take the equipment to wear out, labor costs, and the comfort and convenience provided by the equipment. Only at one location in Michigan, Sturgis, has a digester had an acceptable payback period. At other Michigan digesters, it became clear that the digester was in no way going to break even in two to four years. As time went on, maintenance increased, further extending the payback period. Within the first five to eight years of development most Michigan digesters were in the situation of not being able to meet any realistic payback period and therefore they were considered not economically feasible. Interviews with farmers had suggested that this was the case.

In Michigan, it is not unreasonable to consider payback periods of a minimum of 7 to 10 years for a farm-based anaerobic digester. Few farms are able to make those type of long-term investments. When planning a digester, it is not wise to cut costs up-front. If a digester is to work for 10 to 15 years, a level of engineering will need to be applied which is consistent with that goal. However, this type of engineering work will usually have a higher cost. If a digester is planned and built on a lowest bid basis, the cheaper design will usually-win. However, if the cheaper unit is installed and subsequently fails due to under-design the system will likely fail. Modern anaerobic digesters can be built having a seven year payback period. In Europe, there have been many examples of those types of systems. Digesters can be constructed to have a three year payback period, but in most of those cases the designs and quality of the parts may be inadequate.

Maintenance costs have also been a barrier to the success of digesters. When the staff of the farm has to spend time working on the digester, that time is related to cost of the worker and on smaller farms the labor is often shifted from other activities. In some cases, the mistake was made of not planning for the operation and maintenance cost creating cost overruns for the digester. In considering the overall economics of the digester, the costs of maintenance should be estimated (and to be safe overestimated). At the Sturgis digester, maintenance costs include oil changes for the engine fueled by the biogas, and the shutting down of the system to clean the heat exchangers every four years. The oil change takes one to two hours for every 2000 miles (equivalent) of engine wear and the cleaning of the digester takes a few days.

External to the farm, “cheap” energy costs are another economic barrier to digesters. Farmers have little economic need to produce their own energy. On most Michigan dairy farms, I have found that total energy expenditures amount to about three to five percent of the total operating costs for the farm. With energy costs being so small as compared to the total operational costs, farmers have little incentive to investigate how to reduce that cost. They do not think that it is worth their while to invest in supplying their own energy. In discussions with farmers, energy costs (electric energy rates currently at $0.08 - $0.12 / Kwh) would have to triple for them to consider investigating how to reduce those costs. If energy costs would account for a greater share of the total operational costs (perhaps 20% to 30%) then farmers would look for ways to reduce that cost. In the current energy pricing climate, there is little incentive for a farmer to become energy independent.

As previously discussed, when there is a real of perceived threat of energy cost increases farmers may want to act to buffer their businesses against cost fluctuations. Utility supplied electricity is generally viewed by the farm community as risk-free and assured. Farmer's see little need to become competitors with their current energy suppliers. However, even if the current electricity energy supply situation does not make it attractive now for farmers to consider producing their own energy, one cannot assume that situation will remain unchanged. One variable that may change this situation is the deregulation of Michigan' electric utilities. Historically, regulation encouraged electric utilities to become vertically integrated. In other words utilities own the systems for generation, transmission, and distribution of electricity. In deregulation, the opposite of this vertical integration is promoted. It is uncertain how farmers will be effected by deregulation. Since they are in rural areas, spatially separated by large distances, and sometimes at the end of the transmission lines a greater cost may be shifted to them to pay for the electric distribution infrastructure they require. If these stranded costs (costs incurred over time by the utility in a vertically integrated system) are shifted to rural electricity user farmers would again have an immediate economic reason to consider producing their own energy. With many future energy cost uncertainties facing the farmer, it is always prudent to be in a position to reduce or control energy costs. Anaerobic digestion is one way in which cost farmers can produce a portion of their own energy to buffer their business against energy cost fluctuations.

Section Five: Conclusion -- **An Existing Potential But Uncertain Future**

As it has been demonstrated, both nationally and internationally, digesters are a working technology that has been successfully applied on farms. However, the Michigan success rates (success being defined as having an operating digester) for anaerobic digesters have been rather low. Historically, five out of six digesters have failed, only one digester is operational in Sturgis, and the future for farm based anaerobic digestion in Michigan is uncertain. The successful anaerobic digester in Sturgis has shown, that a farmer must closely match the digester's operation to the farm's resource management regime. By establishing these matches in the planning stages, digesters can create both monetary and non-monetary benefits for the farmer.

The future of farm-based anaerobic digestion in Michigan is not clear. Arguably, due to recent digester history some Michigan farm practitioners have written off anaerobic digestion as a dead technology. For the short-term, one may be able to have partial justification for making such a claim. However, for the long-term, one cannot assume that the current social, political, and economic trends discouraging forms of alternative energy, such as anaerobic digestion, will continue to remain static. As digesters can provide multiple benefits to problems faced by the Michigan's farmer, some of them may find to situations where employing such technology can give them a competitive advantage. As economic and regulatory changes are likely to force farmers to internalize their external costs associated with energy and waste management, an apparatus that can address issues of energy costs, waste management, and farm odors, will develop niche markets. In addition, the reliability of digesters in the post 1972-1982 period has increased due to simplified design. As **is the** case with the development and dissemination of any technology, creative applications of existing technology will need to be employed in order to facilitate new experimentation showing how digesters can be integrated into the modern farming system.

While it is impossible to cover all the complex factors which had influenced and will influence Michigan farm-based anaerobic digestion in this report, a very important conclusion of this report is that digesters have difficulty competing on the basis of the value of their energy recovery alone. Since energy costs reflect short-term market driven factors more than the actual costs of the long-term energy production, consumption, and disposal cycles, biomass energy will have a difficult time competing with other sources of non-renewable energy. For that reason, some people view the primary benefit of anaerobic digesters as waste treatment, with energy production being a secondary benefit. It is clear that anaerobic digesters need to be valued on their ability to both solve waste management problems and as well on as their ability to provide energy.

In the near-future, it is not likely that farm-based anaerobic digestion will be able to contribute a significant amount of energy to Michigan's supply mix. However, one should not overlook the usefulness of digestion in niche market situations. Specifically, digesters can be an feasible option when considering their abilities for reducing waste treatment and disposal costs, providing a cost-effective way for complying with environmental regulations, and also producing energy. In terms of biomass resource availability and current technological capabilities, there is much room for expansion of the use of anaerobic digesters on Michigan's farms.

Section Six: Sources -- Interview Citations and Bibliography

6.1- interview Citations

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